

# Soil campodeids (Diplura, Campodeidae) of Eastern Europe, in Romanian and Bulgarian reliefs

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## Abstract

This study presents data on soil campodeids collected in Romania and Bulgaria in recent years. The collection comprises 12 species of genus *Campodea* Westwood, 1842 in total. A new species, *Campodea (Dicampa) transylvanica* Sendra, **sp. nov.** is described from Zarand and Făgăraș mountains in Romania. *Campodea (Campodea) plusiochaeta* Silvestri, 1912 is newly recorded for the Romanian fauna, while *Campodea (Paurocampa) ruseki* Condé, 1966 represents a new record for Bulgaria. New distributional data are also provided for the remaining ten species.

**Key words:** *Campodea*, *Dicampa*, new records, new species, *Paurocampa*, taxonomy



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## Introduction

The first records of Campodeidae species (*Campodea staphylinus* Westwood, 1842 and *Campodea fragilis* Meinert, 1865) from Romania were published by Vellay (1900) and later cited by Stach (1929). However, both species are now considered misidentifications (Sendra et al. 2012). Years later, in Bulgaria, Silvestri (1931) described three species of campodeids from cave habitats: *Campodea (Dicampa) frenata* Silvestri, 1931, *Plusiocampa bulgarica* Silvestri, 1931, and *Plusiocampa bureschi* Silvestri, 1931. Later, Drěnovski (1937) reported three species from soil habitats in Bulgaria: *Campodea (Dicampa) malpighii bulgarica* Drěnovski, 1937, *Campodea witoschensis* Drěnovski, 1937, and *Plusiocampa montana* Drěnovski, 1937. However, Paclt (1957, 1969) considered each a nomen nudum, and the first two were respectively assigned to *Campodea (Dicampa) frenata* Silvestri, 1931 and *Campodea (Paurocampa) suensoni* Tuxen, 1930 while the third remained without assignation. During 1950s and 1960s, several contributions significantly improved our understanding of the soil and cave Campodeidae of the Carpathians (Romania) and the mountains in Bulgaria (Ionescu 1951, 1955; Rusek 1965a;

Pacit 1969). In the 21<sup>st</sup> century, the diversity of soil species increased to 18 species in Romania (Sendra et al. 2012) and seven species in Bulgaria (Sendra and Georgiev 2021). In addition to the soil-dwelling Campodeidae fauna, nine cave-adapted species have been described or reported: five species from caves in the southern Carpathians (Ionescu 1955; Condé 1991, 1993, 1996; Sendra et al. 2012) and six species from caves in Bulgaria (Silvestri 1931; Bareth and Condé 2001).

The aim of this study is to enhance the understanding of the family Campodeidae within the basal hexapod class Diplura in the Carpathians and Balkan Mountains in Romania and Bulgaria by providing new records and distributional data, describing a new species, and publishing taxonomic and distributional remarks on certain taxa.

In total, 222 specimens from 44 sampling sites in Romania and one site in Bulgaria were examined, based on a collection provided by C. Fiera collected between 2018 and 2021. Additional material from six localities in Bulgaria was collected by Boyan Petrov, Petar Beron, and Pavel Stoev, zoologists at the National Museum of Natural History, Bulgarian Academy of Sciences.

## Materials and methods

Most of the Diplura specimens were extracted from samples of leaf litter, soil, and mosses using Berlese funnels. The material has been deposited in the private collection of Alberto Sendra, València, Spain (Coll. AS) and most of specimens were mounted on slides using Marc André II medium. These were observed and identified using a phase-contrast microscope, and measurements were taken with an ocular micrometre.

Photomicrography was performed with a stereo microscope (Leica M165C) with an integrated capture system image (LAS v. 4.13) and software LCS Lite, and a compound microscope with a photographic camera K3 C/M and the software LCS Lite. We used the software Helicon Focus to combine photos of a specimen at different levels of focal planes, which helped achieve a more accurate and complete illustration. Several specimens for SEM photography (Hitachi S-4900) were coated with palladium-gold.

The type and studied material are kept at the following institutions:

<b>Coll. AS</b>	private collection of Alberto Sendra, València, Spain
<b>IBB</b>	Institute of Biology Bucharest, Romanian Academy
<b>NMNHS</b>	National Museum of Natural History at the Bulgarian Academy of Sciences.

## Results

### *Campodea (Campodea) magna* Ionescu, 1955

**Material examined. ROMANIA** • 1 ex., Bârgău Mountains: Leşu, Bistriţa-Năsăud County, 47.289248°N, 24.756708°E, 749 m a.s.l., beach, rarely fir, litter, 02.11.2021, C. Fiera leg.; • 1 ex., RO, Bârgău Mountains: Lunca Ilvei, near Pepiniera Silhoasa, Bistriţa-Năsăud County, 47.346245°N, 25.015375°E, 749 m a.s.l.,

mixed forest (fir and beech), soil, 04.11.2021, C. Fiera leg.; • 2 ex., Doftana Valley: Şotriile, 45.227694°N, 25.729119°E, 609 m a.s.l., beech forest, soil, 18.11.2016, C. Fiera leg.; • 7 ex., Bârgău Mountains: Tureac, site 1, Bistriţa-Năsăud County, 47.257408°N, 24.856696°E, 862 m a.s.l., beech forest, soil, 18.08.2018, C. Fiera leg.; • 1 ex., Suceava County: Zamostea-Lunca forest, 47.870137°N, 26.252775°E, 290 m a.s.l., old oak (120 years old, rarely 180 years old), in association with ash, aspen, maple, hornbeam, litter, 08.08.2019, C. Fiera leg.

**Habitat and distribution.** Soil-dwelling species found in several localities from the southern Carpathians (Ionescu 1955; Sendra et al. 2012) and recently in Bulgaria (Sendra and Georgiev 2021). The species is also known from the northern Anatolia (Sendra et al. 2010).

### ***Campodea (Campodea) plusiochaeta* Silvestri, 1912**

**Material examined. ROMANIA** • 1 ex., Alba County: Cenade, 46.036341°N, 24.007781°E, 436 m a.s.l., vineyards, soil, 10.09.2020, M. Şandor leg.; • 1 ex., Suceava County: Iacobeni, 47.446179°N, 25.311171°E, 895 m a.s.l., mixed forest (fir, larch, hornbeam), soil and litter, C. Fiera leg.

**Habitat and distribution.** A soil-dwelling species, living under stones or among the alluvial debris (Condé 1960) which is common under barks or moss. It is also found in dry environments, burrows of mammals or gardens, sometimes reaches high altitude in mountains. It is one of the most widespread species collected at many sites of the Euro-Mediterranean region: British Isles (Condé 1961), southern Jutland and southern Scandinavian peninsulas (Silvestri 1912; Arevad 1957; Olsen 1996), North Africa (Condé 1947a, 1953), throughout the Iberian Peninsula (Sendra and Moreno 2004), throughout continental Europe including west, central, and eastern Europe (Silvestri 1912; Pagés 1951; Rusek 1964; Stach 1964; Wygodzinsky 1941; Paclt 1965), Apennine Peninsula (Silvestri 1912; Ramellini 1995; 2000), Balkan Peninsula (Condé 1984), and Anatolia (Sendra et al. 2010). The easternmost localities are in western Russia (Silvestri 1912; Rusek 1965b) close to the 60° parallel.

**Remarks.** New record for the Romanian fauna.

### ***Campodea (Campodea) taunica* Marten, 1939**

**Material examined. ROMANIA** • 1 ex., Dâmboviţa County: Springs Complex of Corbii Ciungi, near Corbii Mari County, 44.524361°N, 25.512138°E, 122 m a.s.l., scrubs, soil, M. Manu leg.

**Habitat and distribution.** A soil-dwelling species that is distributed throughout Central Europe, including France (Husson 1946; Pagés 1951), Central Germany (Paclt 1961), Swiss Alps (Orelli 1956), and reaching as far as the Romanian Carpathians (Ionescu 1951, 1955; Sendra et al. 2012) and Serbia (Blesić 2000a). Surprisingly, it has not been found yet in the Czech Republic or Slovakia. Outside Central Europe, it has been quoted in the Pontic Mountains and the northern part of Anatolia (Sendra et al. 2010).

***Campodea (Campodea) wallacei* Bagnall, 1918**

**Material examined. ROMANIA** • 4 ex., Bucegi Massif: Sinaia, Prahova County, 45.333328°N, 25.549175°E, 858 m a.s.l., in the city of Sinaia, park, under *Larix* sp., 23.09.2019, C. Fiera and M.W. Weiner leg.

**Habitat and distribution.** A soil-dwelling species, which is also found in cave habitats (Condé 1956, 1962; Sendra et al. 2013). It is distributed in England (Bagnall 1918), southern Scandinavian Peninsula (Agrell 1944), Maritime Alps (Bareth and Condé 1985; Ramellini 2000), France (Condé 1947b, 1947c, 1950; Pagés 1951), Germany (Christian 2003) and the Dinaric Mountains (Blesić 1998a, 1998b, 2000a, 2001). The species has been recorded from Romania by Ionescu (1951, 1955) and Sendra et al. (2012).

***Campodea (Dicampa) apula* Silvestri, 1912**

**Material examined. ROMANIA** • 1 ex., Făgăraş Mountains: Nucşoara, Argeş County, 45.417893°N, 24.733326°E, 1196 m a.s.l., mixed forest (*Fagus sylvatica*, *Betula pendula*, *Alnus viridis*, *Sambucus* sp.), litter, 10.11.2021, C. Fiera and I. Vicol leg.

**Habitat and distribution.** A soil-dwelling species known from Foggia, Italy (Silvestri 1912), the Carpathian Mountains across Slovakia, Poland, and Romania (Ionescu 1951, 1955; Paclt 1961; Szeptycki 1974), and extending to the western border of the Caucasus.

***Campodea (Dicampa) campestris* Ionescu, 1955**

**Material examined. ROMANIA** • 5 ex., Făgăraş Mountains: Sâmbăta de Sus, Braşov County, 45.681608°N, 24.791662°E, 746 m a.s.l., mixed forest (fir and beech), soil, 11.11.2021, C. Fiera and I. Vicol leg.; 1 ex. Doftana Valley: Voila, 45.166241°N, 25.753028°E, 600 m a.s.l., sessile oak and beech, soil, 14.07.2018, C. Fiera leg.

**Habitat and distribution.** A soil-dwelling species distributed from the southern Carpathians to the Balkan Mountains (Rusek 1965a; Blesić 1984, 1998a, 2000a; Sendra et al. 2012).

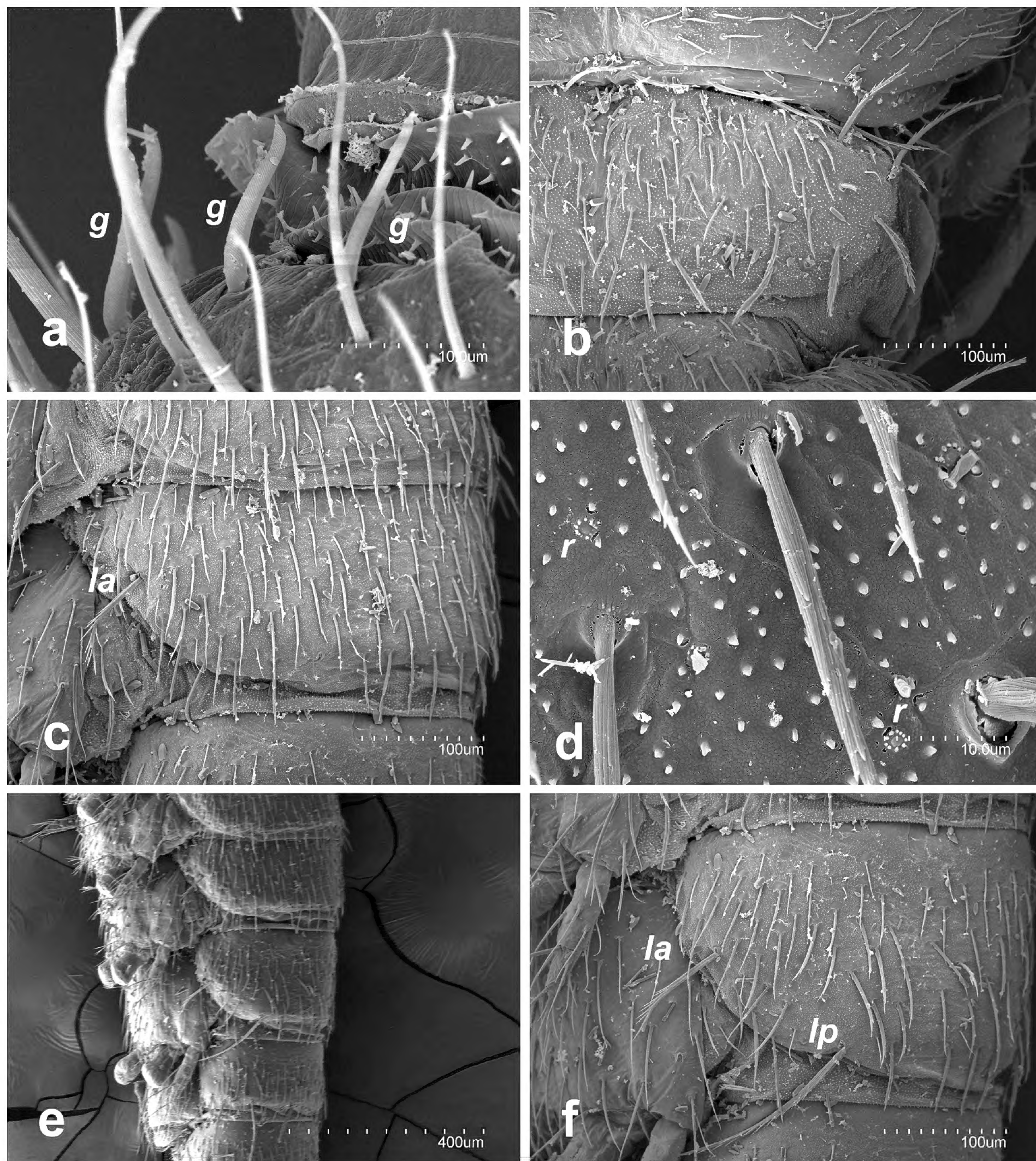
***Campodea (Dicampa) frenata* Silvestri, 1931**

Fig. 1a–f

**Material examined. BULGARIA** • 3 ex., Vrachanski Balkan Nature Park, hut Purshovitza, 1400 m a.s.l., forest, 12.07.1993, B. Petrov leg.; • 5 ex. Central Balkan National Park, hut Rai, 1250 m a.s.l., foliage, 08.12.1992, B. Petrov leg.; • 5 ex., Western Rhodopes Mts., village Mostovo, under stones, 14.03.1992, B. Petrov leg.; • 2 ex., Western Rila Mts., near Popovski ezera Lakes, 2350 m a.s.l., 25.07.1993, B. Petrov leg.

**Taxonomic notes.** Specific observations using scanning electron microscopy reveal short and slightly thick gouge sensilla on the antennomeres (Fig. 1a); tergites: dense microdenticles with rosette glands along with well-barbed





**Figure 1.** *Campodea (Dicampa) frenata* Silvestri, 1931, specimen in Coll. AS. **a** lateral anterior view of a medial antennomere **b** pronotum **c** lateral view of abdominal segment 6 **d** detail of pronotum **e** lateral view of abdominal segments 6–8 **f** lateral view abdominal segment 7. Abbreviations: **g** gouge sensillum, **la** lateral anterior macrosetae, **r** rosette gland, **lp** lateral posterior macrosetae.

macrosetae; thick and well-barbed marginal setae, in addition to clothing setae with one or two distal barbs (Fig. 1b–f).

**Habitat and distribution.** A soil-dwelling species that is only occasionally found in caves (Silvestri 1931; Bareth and Condé 2001). It is distributed throughout the Carpathians Mountains (Ionescu 1955; Rusek 1964), and extends southward into the Balkan Mountains (Paclt 1969; Blesić 1984; 2000a).

***Campodea (Dicampa) propinqua* Silvestri, 1932**

Figs 2a–f, 3a–c

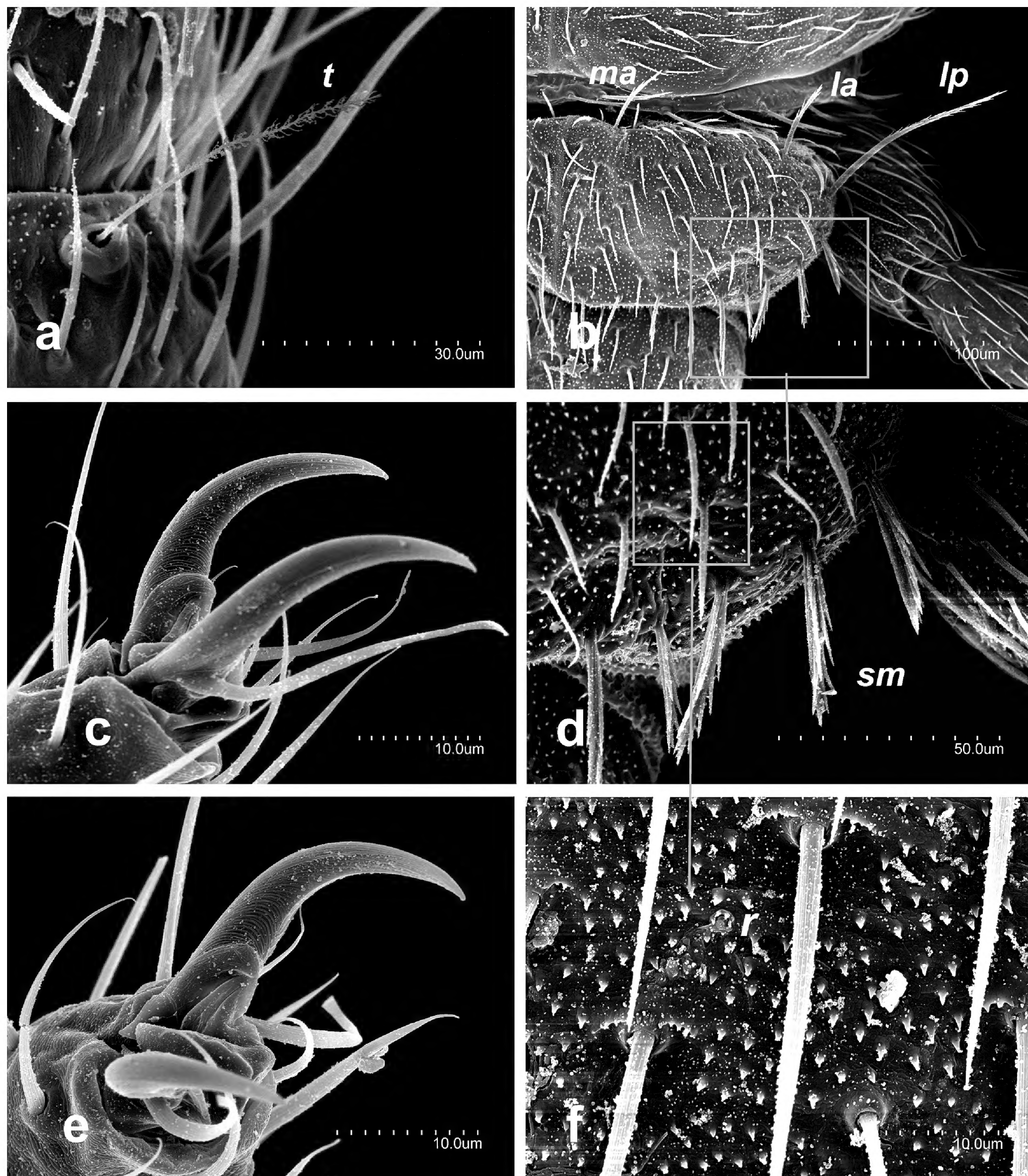
**Material examined.** ROMANIA • 1 ex., Bârgău Mountains: Valea Mare, Bistrița-Năsăud County, 47.481778°N, 24.999045°E, 762 m a.s.l., spruce forest, soil, 04.11.2021, C. Fiera leg.; • 1 ex., Bârgău Mountains: Șanț, Bistrița-Năsăud County, 47.50723°N, 24.970762°E, 826 m a.s.l., cutted spruce forest, litter, 04.11.2021, C. Fiera leg.; • 15 ex., Brașov County: Pârâul Rece, 45.512108°N, 25.507398°E, 1073 m a.s.l., spruce forest, litter, 12.11.2021, C. Fiera and I. Vicol leg.; • 5 ex., Făgăraș Mountains: Cârțișoara, Sibiu county, 45.670567°N, 24.590975°E, 927 m a.s.l., beech forest, soil, 10.10.2020, C. Fiera and I. Vicol leg.; • 5 ex., Făgăraș Mountains: Turnu Roșu, Sibiu county, 45.616342°N, 24.323312°E, 704 m a.s.l., mixed forest (spruce, fir, beech), predominantly spruce. litter, 11.11.2021, C. Fiera and I. Vicol leg.; • 1 ex., Făgăraș Mountains: Cârțișoara, Sibiu county, 45.671965°N, 24.791662°E, 808 m a.s.l., beech forest, litter, 11.11.2021, C. Fiera and I. Vicol leg.; • 1 ex., Făgăraș Mountains: near Berivoi Monastery, Brașov County, 45.687445°N, 24.970958°E, 709 m a.s.l., beech forest, rarely fir, litter, 12.11.2021, C. Fiera and I. Vicol leg.; • 3 ex., Suceava County: Iacobenii, 47.446179°N, 25.311171°E, 895 m a.s.l., mixed forest (fir, larch, hornbeam), soil and litter, C. Fiera leg.; • 2 ex., Gorj County: Râncă locality, 45.301415°N, 23.680959°E, 1622 m a.s.l., spruce forest, soil and litter, 17.06.2021, C. Fiera leg.; • 1 ex., Zarand Mountains, site 1, Căsoaia, near Arăneag, Arad county, 46.225324°N, 21.764489°E, 226 m a.s.l., mixed forest (*Abies alba*, *Fagus sylvatica*, *Quercus frainetto*, *Carpinus betulus*, *Acer campestre*), soil, 10.11.2020, C. Fiera and I. Vicol leg.; • 1 ex., Zarand Mountains, site 4, Milova, Arad county, 46.124375°N, 21.801121°E, 191 m a.s.l., mixed forest (*Picea abies*, *Fagus sylvatica*, *Pinus nigra*, *Acer campestre*, *Quercus* sp., *Aces pseudoplatanus*), soil, 11.11.2020, C. Fiera leg. and I. Vicol; • 2 ex., Zarand Mountains, site 5, Bârzava, Arad county, 46.127396°N, 21.986602°E, 168 m a.s.l., mixed forest (*Fagus sylvatica*, *Quercus petraea*, *Avium cerasus*), soil, 11.11.2020, C. Fiera and I. Vicol leg.; • 1 ex., Zarand Mountains, site 6, Conop, Arad county, 46.098845°N, 21.903658°E, 165 m a.s.l., mixed forest (*Quercus cerris*, *Q. frainetto*, *Acer campestre*, *Fagus sylvatica*, *Ligustrum vulgare*, *Robinia pseudocacia*, *Sorbus* sp., *Carpinus betulus*, *Sorbus terminalis*), soil, 11.11.2020, C. Fiera and I. Vicol leg. **BULGARIA** • 1 ♂, 1 ♀, Pirin Mts., 6 km of Predela, MSS trap, alt. 676 m a.s.l., 16.06.2006, P. Stoev, B. Petrov leg.

**Taxonomic notes.** The morphological taxonomic features observed in the studied specimens under an optical microscope show no differences from the Iberian specimens. However, a molecular analysis should be conducted to confirm whether these geographically distant populations belong to the same species.

Specific observations using scanning electron microscopy reveal large embase of antennal trichobothria (Fig. 2a), dense microdenticles (Fig. 2b, d) including rosette-type glands on all tergites (Fig. 2f), well-barbed macrosetae (Fig. 2b), and clothing setae with a single distal barb (Fig. 3a, b). Additionally, the stylus setae are smooth, with the apical one featuring two long basal denticles (Fig. 3c). Claws are simple, with a protuberance between them (Fig. 2c, e).

**Habitat and distribution.** A soil-dwelling species known from a single locality in the western Subbaetic Mountains, southern Iberian Peninsula (Silvestri 1932a), and inhabiting colluvial scree slopes in central Iberia (Sendra et al. 2017). Reported from Romania by Ionescu (1951, 1955) and Italy by Ramellini (1990).

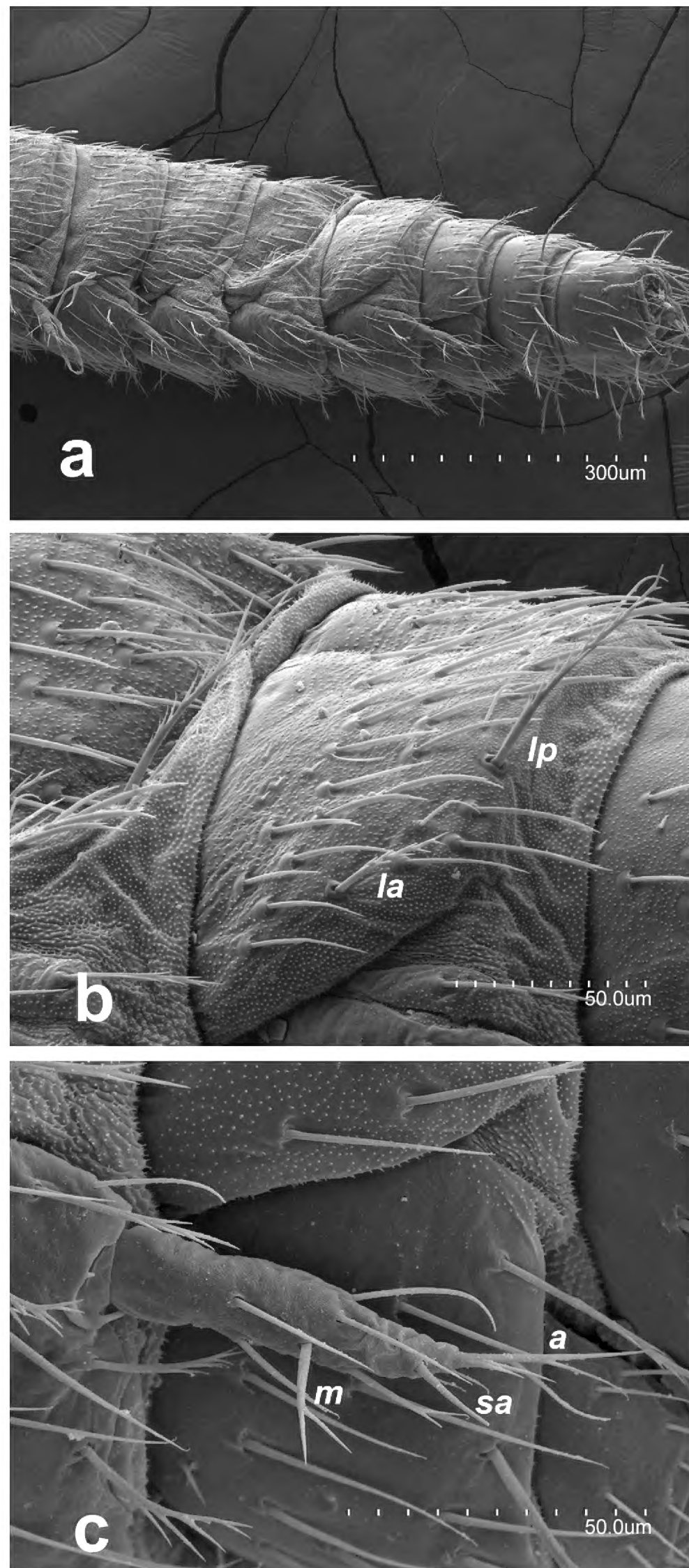




**Figure 2.** *Campodea (Dicampa) propinqua* Silvestri, 1932, specimen in Coll. AS **a** latero-anterior view of third antennomere **b** pronotum **c** pretarsus metathoracic leg **d** latero-anterior view of pronotum **e** pretarsus metathoracic leg **f** detail pronotum. Abbreviations: **t** trichobothria, **ma** medial anterior macrosetae, **la** lateral anterior macrosetae, **lp** lateral posterior macrosetae, **sm** marginal setae, **r** rosette gland.

### *Campodea (Dicampa) sprovieri sprovieri* Silvestri, 1932

**Material examined.** **ROMANIA** • 1 ♀, Bârgău Mountains: Leşu, Bistriţa-Năsăud County, 47.289248°N, 24.756708°E, 749 m, beach, rarely fir, litter, 02.11.2021, C. Fiera leg.; • 1 ♀, 1 ♂, Braşov County: Pârâul Rece, 45.515038°N, 25.503134°E,



**Figure 3.** *Campodea (Dicampa) propinqua* Silvestri, 1932, specimen in Coll. AS **a** abdomen segments 4–10 **b** lateral view abdominal segment 7 **c** stylus abdominal segment 7. Abbreviations: **la** lateral anterior macrosetae, **lp** lateral posterior macrosetae, **m** medial setae, **sa** subapical setae, **a** apical setae.

994 m a.s.l., spruce forest, soil, 14.07.2018, C. Fiera leg.; • 2 ♂, 3 ♀, 1 juv., Vrancea County: Brădăceşti (near Nereju), 45.697641°N, 26.671177°E, 623 m a.s.l., coniferous forest (*Pinus* sp.), soil, 27.05.2021, C. Fiera leg.; • 1 ♂, 2 ♀, Suceava County: Iacobeni, 47.446179°N, 25.311171°E, 895 m a.s.l., mixed forest (fir,



larch, hornbeam), soil and litter, C. Fiera leg.; • 1 ♀, Suceava County: Pătrăuți forest near Răuțeni locality, 47.840511°N, 25.056427°E, 344 m a.s.l., mixed forest (beech, oak, and hornbeam), soil, 13.04.2021, C. Fiera leg.; • 1 juv. Brașov County: Prejmer, site 1, 45.730329°N, 25.737091°E, 510 m a.s.l., mixed forest (maple, lime, hornbeam), soil, 15.11.2018, C. Fiera and Weiner M.W. leg.; • 3 ♀, 2 ♂, 3 juvs, Brașov County: Prejmer, site 3, 45.75037°N, 25.723362°E, 510 m a.s.l., oak forest (*Quercus cerris*), 100 years old, 15.11.2018, C. Fiera and Weiner M.W. leg.; • one juv., Brașov County: Prejmer, site 4, 45.753624°N, 25.707257°E, 501 m a.s.l., oak forest (*Quercus cerris*), less than 70 years old, 15.11.2018, C. Fiera and Weiner M.W. leg.; • 4 ex., Cheile Zugreni, between Bistriței and Giumalău mountains, 47.407101°N, 25.545952°E, 770 m a.s.l., pine and spruce forest, 18.08.2018, C. Fiera leg.; • 1 ♂, Suceava County: Dornișoara, 47.213982°N, 25.06118°E, 1109 m a.s.l., spruce forest, 18.08.2018, C. Fiera leg.; • 1 ♀, Brașov County, Hărman, site 2, 45.734179°N, 25.671031°E, 508 m a.s.l., peatbog with oak, soil, 16.11.2018, C. Fiera and Weiner M.W. leg.; • 5 ♂, 6 ♀, 7 juvs and 3 specimens kept for DNA, Bucegi Massif: Sinaia, Prahova county, site 1, 45.351264°N, 25.521893°E, 1288 m a.s.l., spruce forest, soil, 14.07.2018, C. Fiera leg.; • 5 ♀, 5 ♂, 7 juvs and 4 specimens kept for DNA, Bucegi Massif: Sinaia, Prahova county, site 2, 45.357541°N, 25.516975°E, 1386 m a.s.l., spruce forest, soil, 14.07.2018, C. Fiera leg.; • 3 juvs, Buzău County: Siriu, 45.559882°N, 26.178259°E, 658 m a.s.l., beech forest, soil, 27.06.2020, C. Fiera leg.; • 2 ♀, 2 juvs, Doftana Valley: Șotriile, 45.227694°N, 25.729119°E, 609 m a.s.l., beech forest, soil, 18.11.2016, C. Fiera leg.; • 2 ♂, 1 ♀, one juv. and one specimen kept for DNA, Bârgău Mountains: Tureac, site 1, Bistrița-Năsăud County, 47.257408°N, 24.856696°E, 862 m a.s.l., beech forest, soil, 18.08.2018, C. Fiera leg. **BULGARIA** • 1 ♀, 4 juvs, Pirin Mountains, Bansko, 41.77552°N, 23.439216°E, 1784 m a.s.l., spruce forest, soil, 13.08.2018, C. Fiera leg.

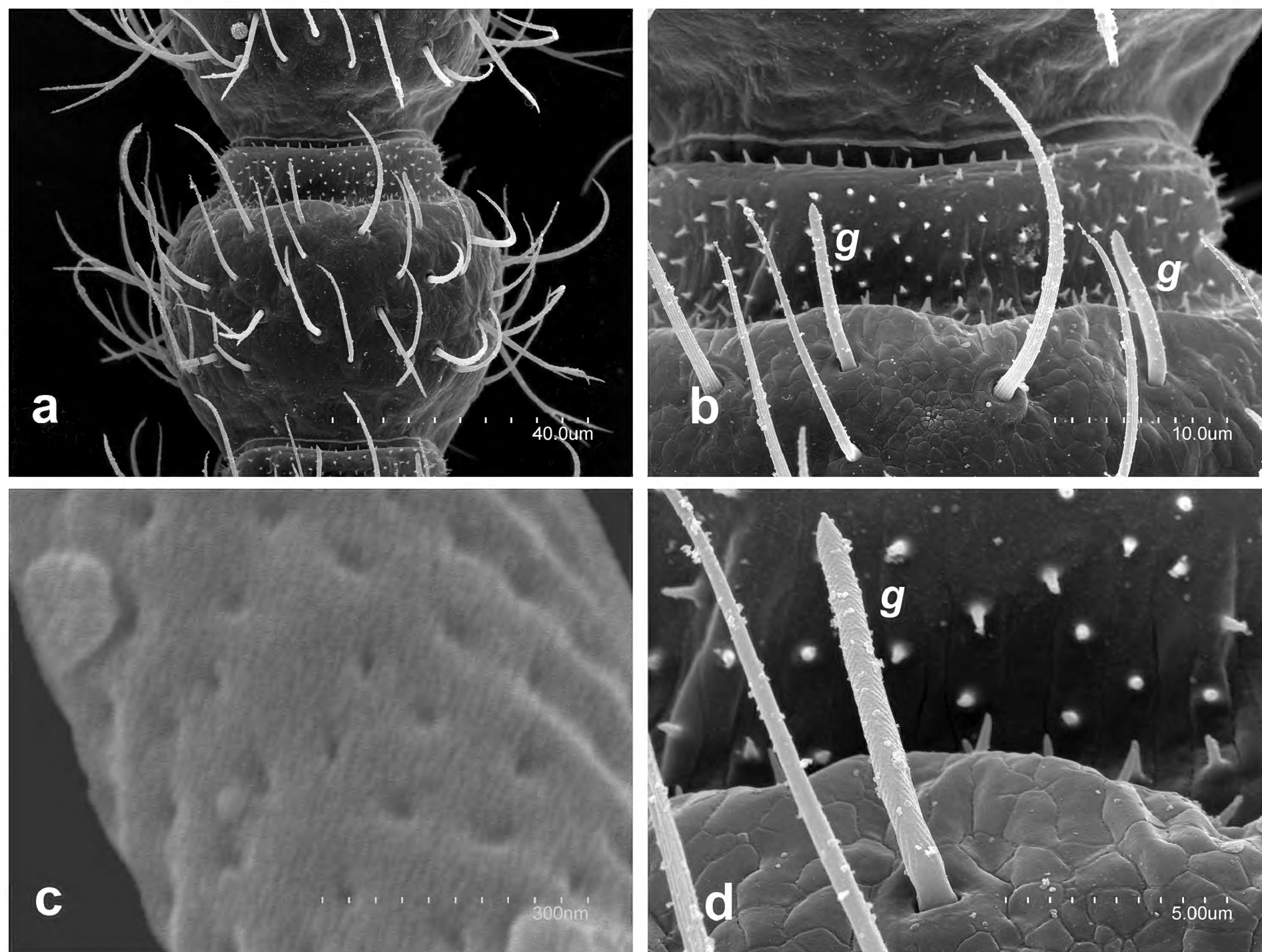
**Habitat and distribution.** A soil-dwelling species which is widely spread around the Balkan Peninsula (Ionescu 1955; Rusek 1965b; Condé 1984; Sendra et al. 2012) and Anatolia (Sendra et al. 2006, 2010), including several Aegean islands (Silvestri 1933; Condé 1984).

***Campodea (Dicampa) transylvanica* Sendra, sp. nov.**

<https://zoobank.org/7655C15C-D6CB-4D70-AD16-DA30DA48A7FC>

Figs 4a–d, 5a–c, 6a, b

**Type material. Holotype. ROMANIA** • ♂; Turnu Roșu (Sibiu County), Făgăraș Mountains (RO Carpathians), soil, 704 m. elevation; mixed forest (spruce, fir, beech) (predominant spruce); 11 November 2021, Fiera C. and I. Vicol leg.; labelled holotype IBB-CTR1. **Paratypes. ROMANIA** • 1 ♀, 2 ♂♂, 2 juvs, Turnu Roșu, Făgăraș Mountains (RO Carpathians), Făgăraș, soil, 704 m elevation, mixed forest (spruce, fir, beech) (predominant spruce), 11 November 2021, Fiera C. and I. Vicol leg., labelled IBB-CTR2-5; • 1 ♀, Turnu Roșu, Făgăraș Mountains (RO Carpathians), litter, 704 m. elevation, mixed forest (spruce, fir, beech) (predominant spruce), 11 November 2021, Fiera C. and I. Vicol leg., labelled IBB-CTR6; • 1 ♂, Cârțișoara, Făgăraș Mountains (RO Carpathians), litter, beach, 11 November 2021, Fiera C and Vicol I. leg., labelled IBB-CTR7; • 3 ♀♀, Cârțișoara, Făgăraș Mountains (RO Carpathians), soil, beach, 11 November 2021, Fiera C. and I.



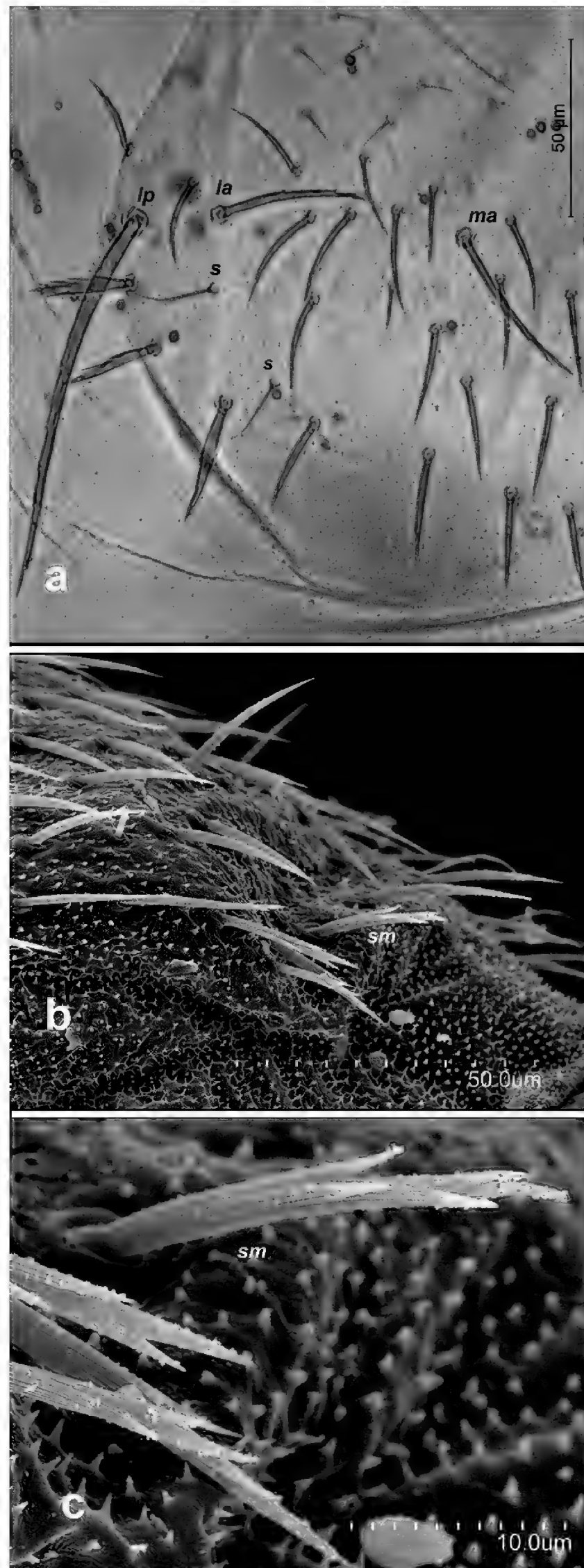
**Figure 4.** *Campodea (Dicampa) transylvanica* Sendra, sp. nov., specimen in Coll. AS **a** medial antennomere **b** latero-anterior view of a medial antennomere **c** detail of gouge sensillum **d** gouge sensillum on antennomere. Abbreviation: **g** gouge sensillum.

Vicol leg., labelled NMNHS-10832-10834; • 1 juv., Radna (Arad County), Zarand Mountains (RO Carpathians), *Quercus cerris*, *Q. frainetto*, *Betula pendula*, 12 November 2020, Fiera C. and I. Vicol leg., labelled IBB-CTR8; • 1 ♀, 1 ♂, Conop (Arad County), Zarand Mountains (RO Carpathians), *Quercus cerris*, *Q. frainetto*, *Acer campestre*, *Fagus sylvatica*, *Ligustrum vulgare*, *Robinia pseudoacacia*, *Sorbus* sp., *Carpinus betulus*, *Sorbus terminalis*, 11 November 2021, Fiera C. and I. Vicol leg., labelled IBB-CTR9-10.

**Other material. ROMANIA** • 1 ♀, Turnu Roşu, Făgăraş Mountains (RO Carpathians), Făgăraş, soil, 704 m elevation, mixed forest (spruce, fir, beech) (predominant spruce), 11 November 2021, Fiera C. and I. Vicol leg, Coll AS.

**Description. Body.** Length 1.9–2.7 mm in male; 2.3–3 mm in females; 1.4–1.7 mm in juveniles. Epicuticle with microdenticles under optical microscope (Fig. 5a) and dense microdenticles under scanning electron microscope (Fig. 5b, c); body with smooth short clothing setae (Fig. 5a–c).

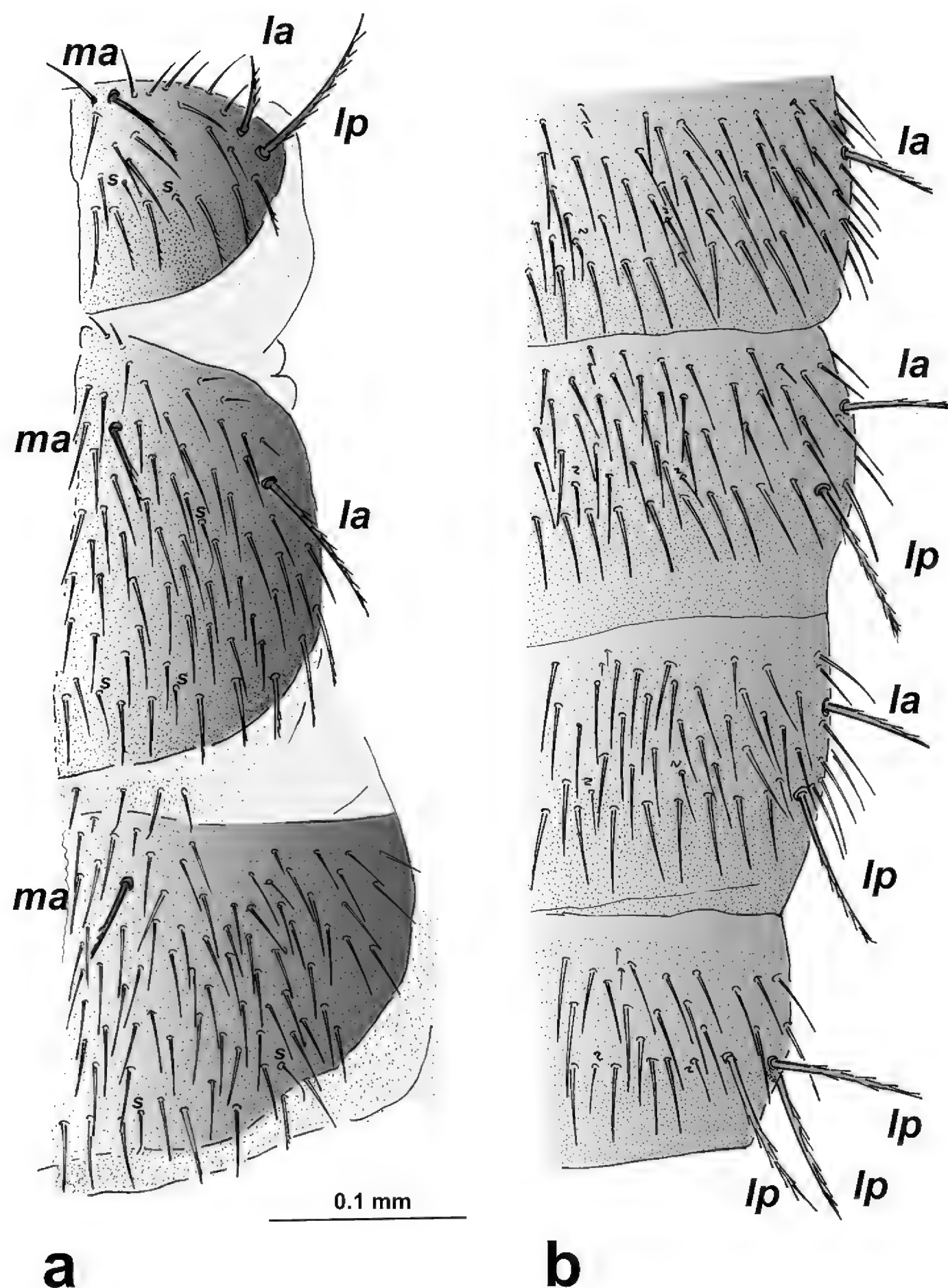
**Head.** Antennae with 15–19 antennomeres in juveniles and adults, 0.53–0.47 shorter than length of the body in juveniles and 0.45–0.31 in adults; central antennomeres as long as wide with one proximal whorl of bifurcated macrosetae and one distal whorl of smooth macrosetae and uneven short smooth setae; in addition to a single distal whorl of  $\leq 4$ –6 gouge sensilla of 5–6 µm long (Fig. 4a–d). Proximal antennomeres with typical trichobothria disposition and



**Figure 5.** *Campodea (Dicampa) transylvanica* Sendra, sp. nov., specimens in Coll. AS.) **a** pronotum **b** latero-posterior view of pronotum **c** detail of latero-posterior pronotum. Abbreviations: **ma** medial anterior macrosetae, **la** latero-anterior macrosetae, **lp** latero-posterior macrosetae, **s** sensillum, **sm** marginal setae.

with small bacilliform sensillum on third antennomere in dorsal position, between *b–c* macrosetae. Plain frontal process with one anterior macrosetae, longer than clothing setae. Three macrosetae each with two or three barbs along each side of insertion line of antennomere with length ratios of *a/i/p*, 11/13/14,





**Figure 6.** *Campodea (Dicampa) transylvanica* Sendra, sp. nov. Holotype IBB-CTR1 **a** pronotum, mesonotum, and metanotum **b** urotergites V–VII. Abbreviations: **ma** medial anterior macrosetae, **la** latero anterior macrosetae, **lp** latero posterior macrosetae, **s** sensillum.

respectively, in holotype. Large suboval labial palps, each with small latero-external sensillum near two guard setae and five normal setae on anterior portion,  $\leq 60$  neuroglandular setae in medial and posterior positions.

**Thorax.** Thoracic macrosetae distribution: pronotum has 1+1 *ma*, 1+1 *la*, 1+1 *lp* macrosetae; mesonotum has 1+1 *ma*, 1+1 *la* macrosetae (Figs 5a, 6a). All macrosetae longer than other setae with barbs in distal  $\frac{1}{2}$ – $\frac{3}{4}$  marginal setae barbed and longer than clothing setae. Short legs, metathoracic legs reach border of fourth abdominal segment. Calcars with two or three long barbs in middle. Each tarsus with two separated ventral rows of slightly and thicker smooth setae among clothing setae. Three long smooth dorsal tarsal and one ventral setae. Subequal simple claws and with smooth lateral processes.

**Abdomen.** Distribution of abdominal macrosetae on tergites (Fig. 6b) shows 1+1 *la* on V, 1+1 *la*, 1+1 *lp* on VI–VII; 3+3 *lp* on VIII and 5+5 *lp* on IX abdominal; *la* macrosetae with barbs in distal ½–1/3 and *lp* macrosetae bear barbs along distal 4/5. Urosternite I with 7+7 macrosetae; urosternites II to VII with 4+4 macrosetae; urosternite VIII with 1+1 macrosetae; urosternal macrosetae of bifurcated, tri or quadrifurcated. Stylus setae with smooth subapical setae, bifurcated ventromedial seta and with two long basal barbs on apical seta.

Secondary sex features. Female urosternite I with subcylindrical appendages, each bearing ≤ 12 glandular *a1* setae in apical field. Male urosternite I with subtrapezoidal appendages, each with apical field of ≤ 17 glandular *a1* setae; a continuous posterior field of ≤ about 100 *g1* glandular setae arranged in 1–3 rows. Two incomplete cerci with basal article plus five primary articles. Internal smooth macrosetae or with one distal barb in proximal articles and other macrosetae with four or five distal barbs; primary articles with up to three whorls of barbed macrosetae, and uneven short smooth setae.

**Taxonomic affinities.** The distribution of urotergal macrosetae in *Campodea* (*Dicampa*) *transylvanica* Sendra, sp. nov. from the Romanian Carpathians matches that of *Campodea* (*Dicampa*) *plagiaria* Silvestri, 1932 from the Baetic and Riff mountains (Silvestri 1932b). However, *Campodea* (*D.*) *transylvanica* Sendra, sp. nov. differs from *C. (D.) plagiaria* in several taxonomic features: 15–19 antennomeres in *Campodea* (*D.*) *transylvanica* Sendra, sp. nov. instead of 26–28 antennomeres in soil populations of *Campodea* (*D.*) *plagiaria*; sensillum on the third antennomere in tergal position in *C. (D.) transylvanica* Sendra, sp. nov. instead of ventral in *C. (D.) plagiaria*; apical barbs on marginal notal setae in *C. (D.) transylvanica* Sendra, sp. nov. instead of thin pine marginal setae in *C. (D.) plagiaria*.

**Etymology.** Named after Transylvania, a historical and cultural region in Central Europe that encompasses central Romania.

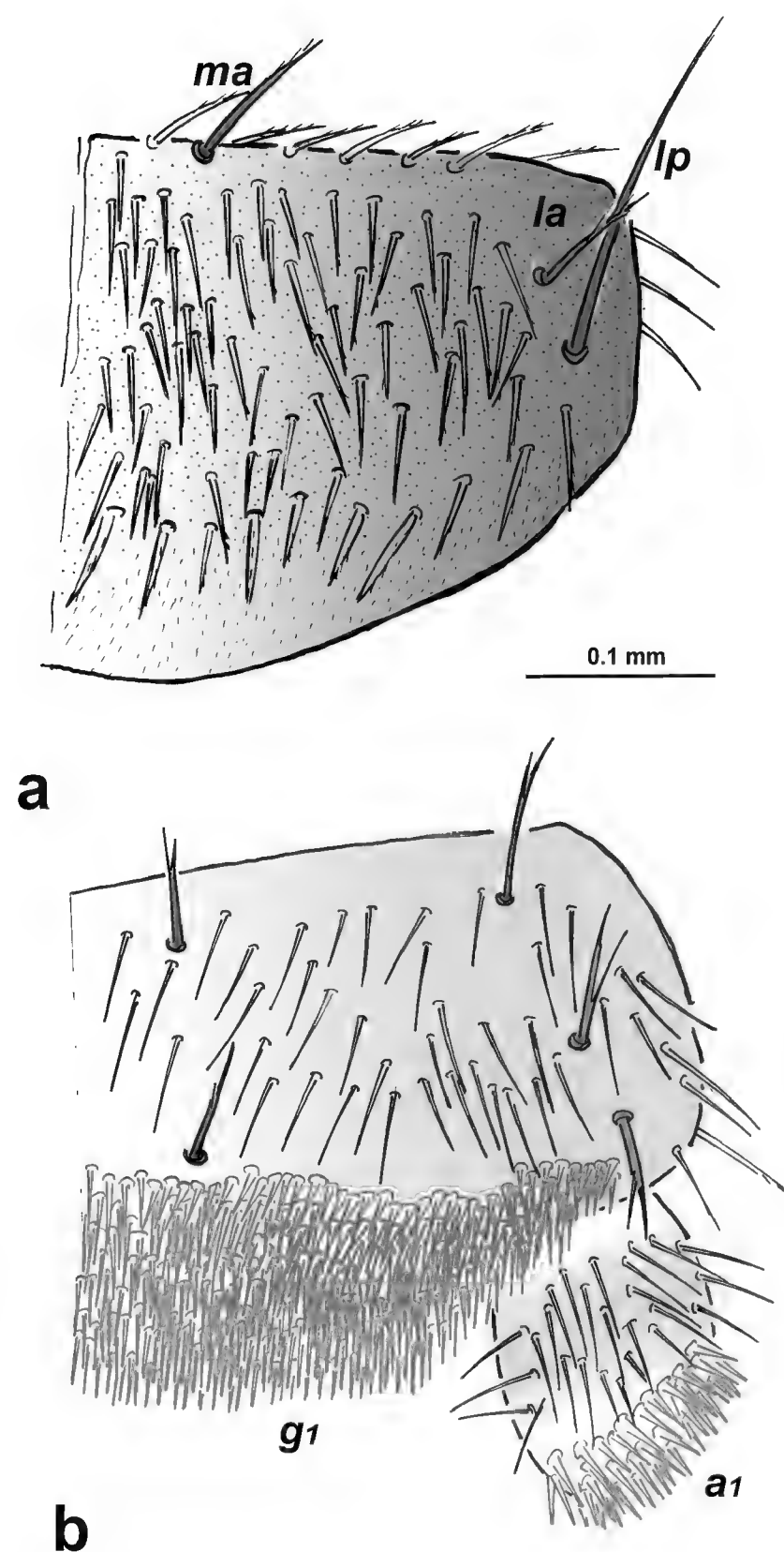
**Habitat and distribution.** A soil-dwelling species that is found in mixed forests in Zarand and Făgăraş mountains. In two localities it co-occurs with *Campodea* (*Dicampa*) *propinqua* Silvestri, 1932.

### ***Campodea* (*Paurocampa*) *ruseki* Condé, 1966**

Fig. 7a, b

**Material examined.** BULGARIA • 2 ♂♂, 1 ♀, Pirin Mountains, Hut Kamenitsa, 1800 m a.s.l., 15.06.1988, P. Beron leg.

**Taxonomic notes.** Observations under the microscope of the studied material have shown several previously unknown features not mentioned in its original description (Condé 1956, 1966). The antennae have 27 antennomeres in a 3.8 mm female, and 25 in 3.95 mm and 4.2 mm males. The apical antennomere has four simple spheroidal olfactory chemoreceptors on the cupuliform organ. A large bacilliform sensillum is present on the third antennomere in tergal position (between b-c macrosetae). Notal tergites bear microdenticles, and the clothing setae are either smooth or have a distal tiny barb (Fig. 7a). The marginal setae are slightly longer and thicker than clothing setae, with a few bars on distal half to two-thirds. The pronotal macrosetae have a few thin tiny barbs on the distal half, with the longest *lp* macrosetae with one or two thin tiny barbs at the distal position. No trochanteral setae were observed in any of the specimens studied.



**Figure 7.** *Campodea (Paurocampa) ruseki* Condé, 1966 **a** pronotum **b** first urosternite of a male. Abbreviations: **ma** medial anterior macrosetae, **la** latero-anterior macrosetae, **lp** latero-posterior macrosetae, **g<sub>1</sub>** glandular setae type g1, **a<sub>1</sub>** glandular setae type a1.

The male urosternite I (Fig. 7b) features slightly spherical appendages, each with an apical field containing  $\leq 40$  glandular a1 setae; a continuous posterior field of  $\sim \leq 240$  g1 glandular setae arranged in 7–9 rows.

**Remarks.** New record for Bulgaria.

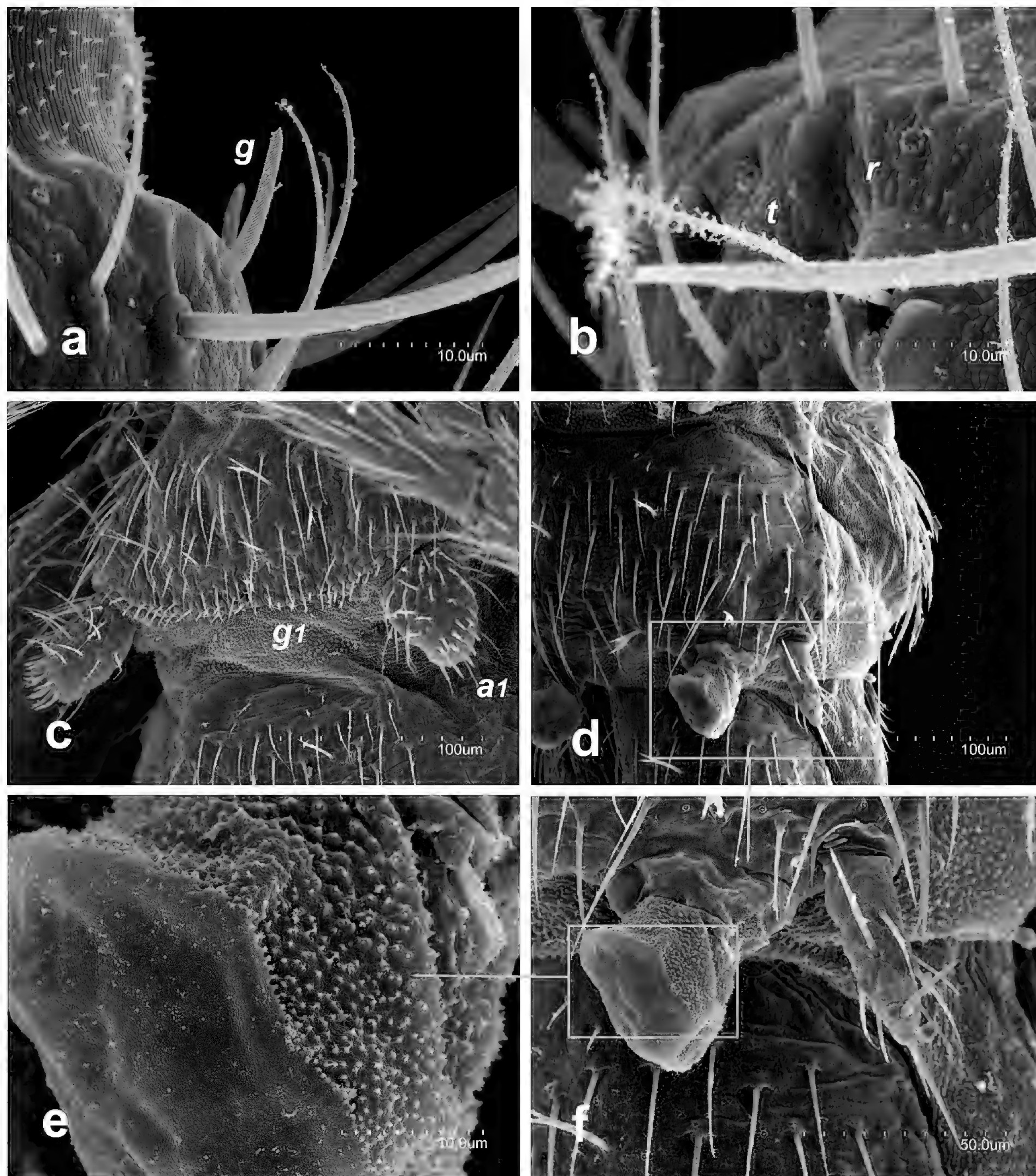
**Habitat and distribution.** A soil-dwelling species that inhabits high altitudes. It is known from two localities in the Austrian Alps (Condé 1954, 1966) and a single locality in the Pirin Mountains of Bulgaria.

### *Campodea (Paurocampa) suenisoni* Tuxen, 1930

Fig. 8a–f

**Material examined. ROMANIA** • 3 ♂, 1 ♀, 4 juvs, Bârgău Mountains: Leșu, Bistrița-Năsăud County, 47.289248°N, 24.756708°E, 749 m, beach, rarely fir, litter, 02.11.2021, C. Fiera leg.; • 2 juvs, Bârgău Mountains: near Ilva Mică, Bistrița-Năsăud





**Figure 8.** *Campodea (Paurocampa) suensoni* Tuxen, 1930 **a** antero-lateral view of a medial antennomere **b** distal portion of third antennomere **c** first urosternite of a male **d** sixth urosternite **e** detail exerted vesicle **f** latero-posterior view of sixth urosternite. Abbreviations: **g** gouge sensillum, **t** trichobothria, **r** rosette gland, **g<sub>1</sub>**, glandular setae type g1, **a<sub>1</sub>**, glandular setae type a1.

County, 47.328709°N, 24.702183°E, 494 m a.s.l., beach forest, litter, 02.11.2021, C. Fiera leg.; • 1 ♀, Bârgău Mountains: Tureac, site 8, Bistrița-Năsăud County, 47.257365°N, 24.857551°E, 872 m a.s.l., beach forest, soil, 03.11.2021, C. Fiera leg.; • 2 ♂, 2 ♀, Făgăraș Mountains: Nucșoara, Argeș County, 45.417893°N, 24.733326°E, 1196 m a.s.l., mixed forest (*Fagus sylvatica*, *Betula pendula*, *Alnus viridis*, *Sambucus* sp.), litter, 10.11.2021, C. Fiera and I. Vicol leg.; • 1 ♂, 1 ♀, 2 juvs,

Suceava County: Iacobenii, 47.446179°N, 25.311171°E, 895 m a.s.l., mixed forest (fir, larch, hornbeam), soil and litter, C. Fiera leg.; • 1 ♀, Argeş County: near Râuşor Lake, 45.397983°N, 25.056427°E, 431 m a.s.l., rocks, soil, 26.07.2020, C. Fiera leg.; • 3 ♀, 6 ♂, 20 juvs and one specimen kept for DNA, Bărgău Mountains: Tureac, site 1, Bistriţa-Năsăud County, 47.257408°N, 24.856696°E, 862 m a.s.l., beech forest, soil, 18.08.2018, C. Fiera leg.; • one juv., Bistriţa-Năsăud County: Valea Străjii near Tiha Bărgăului, 47.211925°N, 24.879244°E, 701 m a.s.l., beech forest, soil, 18.08.2018, C. Fiera leg.; • 2 ♀, Zarand Mountains, site 1, Căsoaia, near Arăneag, Arad county, 46.225324°N, 21.764489°E, 226 m a.s.l., mixed forest (*Abies alba*, *Fagus sylvatica*, *Quercus frainetto*, *Carpinus betulus*, *Acer campestre*), soil, 10.11.2020, C. Fiera and I. Vicol leg. BULGARIA • 2 ♂♂, 2 ♀♀, 3 juvs, Pirin Mountains, above Bansko, 41.77552°N, 23.439216°E, elevation 1784 m, spruce forest, soil, 13.08.2018, leg. C. Fiera; • 2 ex., Pirin Mt., Popina laka Lake, 18 km from Sandanski 1200–1400 m a.s.l., 15.06.1988. P. Beron leg.

**Taxonomic notes.** Observations under electronic scanning microscope shown several taxonomic morphological characters in details: short gouge sensilla on antennomeres (Fig. 8a); trichobothria with large embase (Fig. 8b); male urosternite I (Fig. 8c) with subspherical appendages, each with an apical field containing glandular  $a_1$  setae in addition to a continuous posterior field of  $g_1$  glandular setae arranged in several rows; and, urosternites I–VII with short stylus and large exerted vesicles with two differentiated cuticle areas (Fig. 8d–f).

**Habitat and distribution.** A soil-dwelling species that is found also at the entrances of caves and in their deeper zones when abundant organic matter is available (Condé 1974; Sendra et al. 2012). It is common and well-distributed in Central and Eastern Europe (Tuxen 1930; Condé, 1954, 1966; Paclt and Rusek 1961; Condé 1956; Rusek 1965b; Paclt 1961, 1969; Blesić 1984, 1997, 2000b, 2001; Christian 1992; Sendra et al. 2012), extending its distribution southward into central Italy (Condé 1966; Ramellini 2000).

## Discussion

Campodeids and other Diplura families have been poorly sampled worldwide, despite their omnipresence in soils and subterranean spaces, including caves accessible or not by humans, as noted by Racovitza (1907) and Sendra (2023). Fortunately, thanks to the Emil Racovita Institute of Speleology in Romania and the National Museum of Natural History in Sofia, the soil and caves campodeid fauna of these two countries has been relatively well documented, primarily in five major contributions (Silvestri 1931; Ionescu 1955; Bareth and Condé 2001; Condé 1996; Sendra et al. 2012). Our study has increased the total number of soil and cave campodeids for Bulgaria and Romania from 19 to 22 species, which include three novelties: *Campodea (Paurocampa) ruseki* (new record for Bulgaria), *Campodea plusiochaeta* (new record for Romania), and one new species, *Campodea (Dicampa) transylvanica* Sendra, sp. nov. (Table 1). The soil campodeids in the studied region belong to four genera: *Campodea* Westwood, 1842 with three subgenera *Campodea* s. str. Westwood, 1842 (eight species), *Dicampa* Silvestri, 1932 (nine species) and *Paurocampa* Silvestri, 1932 (two species), *Eutrichocampa* Silvestri, 1902 (one species), *Litocampa* Silvestri, 1933 (one species), and *Plusiocampa* Silvestri, 1912 (one species).

Table 1. Soil campodeid species from Bulgaria and Romania.

Soil species	Country	Reference
<i>Campodea</i> ( <i>Campodea</i> ) <i>fragilis</i> Meinert, 1865	Romania	Ionescu 1955
<i>Campodea</i> ( <i>Campodea</i> ) <i>magna</i> Ionescu, 1955	Bulgaria, Romania	Ionescu 1955; Sendra et al. 2012; Sendra and Georgiev 2021
<i>Campodea</i> ( <i>Campodea</i> ) <i>plusiochaeta</i> Silvestri, 1912	Romania	This study - new species for Romania
<i>Campodea</i> ( <i>Campodea</i> ) <i>pseudofragilis</i> Condé, 1984	Romania	Ionescu 1951, 1955; Sendra et al. 2012
<i>Campodea</i> ( <i>Campodea</i> ) <i>taunica</i> Marten, 1930	Romania	Ionescu 1951, 1955; Sendra et al. 2012
<i>Campodea</i> ( <i>Campodea</i> ) <i>tuxeni</i> Wygodzinsky, 1941	Romania	Sendra et al. 2012
<i>Campodea</i> ( <i>Campodea</i> ) <i>vihorlatensis</i> Paclt, 1961	Romania	Sendra et al. 2012
<i>Campodea</i> ( <i>Campodea</i> ) <i>wallacei</i> Bagnall, 1918	Romania	Ionescu 1951, 1955; Sendra et al. 2012
<i>Campodea</i> ( <i>Dicampa</i> ) <i>apula</i> Silvestri, 1912	Romania	Ionescu 1951, 1955
<i>Campodea</i> ( <i>Dicampa</i> ) <i>campestris</i> Ionescu, 1955	Bulgaria, Romania	Ionescu 1955; Sendra et al. 2012; Rusek 1965a
<i>Campodea</i> ( <i>Dicampa</i> ) <i>caucasica</i> Rusek, 1965	Bulgaria	Sendra and Georgiev 2021
<i>Campodea</i> ( <i>Dicampa</i> ) <i>frenata</i> Silvestri, 1912	Bulgaria, Romania	Ionescu 1951, 1955; Silvestri 1931; Paclt 1969
<i>Campodea</i> ( <i>Dicampa</i> ) <i>malpighii</i> Silvestri, 1912	Romania	Ionescu 1951, 1955
<i>Campodea</i> ( <i>Dicampa</i> ) <i>propinqua</i> Silvestri, 1932	Romania	Ionescu 1951, 1955
<i>Campodea</i> ( <i>Dicampa</i> ) <i>silvicola</i> Ionescu, 1955	Romania	Ionescu 1955
<i>Campodea</i> ( <i>Dicampa</i> ) <i>sprovieri</i> Silvestri, 1933	Bulgaria, Romania	Ionescu 1951, 1955; Sendra et al. 2012; Rusek 1965a; Sendra and Georgiev 2021
<i>Campodea</i> ( <i>Dicampa</i> ) <i>transylvanica</i> sp. nov.	Romania	This study
<i>Campodea</i> ( <i>Paurocampa</i> ) <i>ruseki</i> Rusek, 1965	Bulgaria	This study - new species for Bulgaria
<i>Campodea</i> ( <i>Paurocampa</i> ) <i>suensoni</i> Tuxen, 1930	Bulgaria & Romania	Ionescu 1951, 1955; Sendra et al. 2012; Rusek 1965b; Paclt 1969
<i>Eutrichocampa</i> <i>collina</i> Ionescu, 1955	Romania	Ionescu 1955; Sendra et al. 2012
<i>Litocampa</i> <i>montana</i> (Ionescu, 1955)	Romania	Ionescu 1955; Sendra et al. 2012
<i>Plusiocampa</i> ( <i>Plusiocampa</i> ) <i>humicola</i> Ionescu, 1951	Romania	Ionescu 1951, 1955; Sendra et al. 2012

This biodiversity is higher in terms of both species and genera, including subgenera, than that of other European regions at the same latitude such as Germany, which has a land area similar to that of Bulgaria and Romania combined, and a total of 13 *Campodea* s. str. species. However, France, with nearly twice the land area of Romania and Bulgaria together, has 47 soil and cave species, primarily from the subgenus *Campodea* (32 species) as well as the subgenera *Dicampa* (four species), *Monocampa* Silvestri, 1932 (four species), and *Paurocampa* (two species) plus the genera *Eutrichocampa* (one species), *Litocampa* (two species), *Plusiocampa* (one species), and *Podocampa* Silvestri, 1932 (one species) (Sendra and Reboleira 2020; Sendra et al. 2020). Furthermore, nearby countries such as continental Greece, one third of the combined area of Bulgaria and Romania has eleven species: subgenus *Campodea* (five species), one species in *Dicampa*, one in the subgenus *Paurocampa*, one in *Helladocampa* Condé, 1984, plus three in *Plusiocampa*. In Serbia and Macedonia, with a similar combined area size as continental Greece, there are 19 species distributed within four genera: *Campodea* (8 *Campodea* s. str. species, 5 *Dicampa* species, and 2 *Paurocampa* species), *Eutrichocampa* with two species, *Podocampa* with two species, and finally *Cestocampa* with one species (Sendra and Reboleira 2020; Sendra et al. 2020).



The diversity of soil campodeids in Bulgaria and Romania is consistently higher than in regions at higher latitudes, which is expected due to the decrease in species numbers in northern areas (Sendra et al. 2021a, b). A clear example is the eleven *Campodea* s. str. species inhabiting the United Kingdom and Ireland, a region similar in area to Bulgaria and Romania together. Similarly, only four *Campodea* s. str. species are found in Norway and Sweden (Sendra and Reboleira 2020).

Another notable characteristic of the soil campodeid fauna in Romania and Bulgaria is its diversity in genera and subgenera, comprising four genera and three subgenera with a prevalence of species in the subgenus *Dicampa*. Almost 41% of all species belong to *Dicampa* (nine species). This richness is also high in the southern Mediterranean region, where *Dicampa* likely originated. For example, on the Iberian Peninsula, 30% of species belong to *Dicampa*, and in Morrocco, the figure is 36% (Sendra and Reboleira 2020).

The campodeid diversity in Romania (20 species) compared with Bulgaria (7 species) shows 25% overlap, with five species in common: *C. (C.) magna*, *C. (D.) campestris*, *C. (D.) frenata*, *C. (D.) sprovieri*, and *C. (P.) suenisoni*. However, there is no overlap among the cave-adapted species, which typically have smaller ranges restricted to karstic areas in each region (Bareth and Condé 2001; Sendra et al. 2012).

Currently, three soil species can be considered as endemic: two are exclusive to Transylvania (Romania), *Plusiocampa humicola* and *C. (D.) transylvanica* Sendra, sp. nov., and one is found in Lotrului Mountains (Romania), *Litocampa montana*. All nine cave-adapted species are also endemic, with four limited to Romanian caves and five to Bulgarian caves.

Despite the extensive sampling efforts conducted in both countries, new taxonomic discoveries likely await entomologists and bioespeleologists who explore this primitive and fascinating group of Diplura.

## Additional information

### Conflict of interest

The authors have declared that no competing interests exist.

### Ethical statement

No ethical statement was reported.

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### Author contributions

Conceptualization: AS. Funding acquisition: CF and PS. Supervision: AS. Writing - original draft: AS. Writing - Review and Editing: AS, CF, JS, PS.

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## Data availability

All of the data that support the findings of this study are available in the main text.

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